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Tsuchiya et al.

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(54) **MANUFACTURING METHOD OF PRESS PRODUCT AND PRESS FORMING APPARATUS**

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B21D 22/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B21D 22/02*** (2013.01); ***B21D 22/22*** (2013.01)

(58) **Field of Classification Search**
CPC B21D 22/30; B21D 22/28; B21D 51/26; B21D 22/26; B21D 51/38; B21D 22/22; B21D 24/04; B21D 5/02; B21D 19/08; B21D 22/02
USPC 72/347, 348, 350, 379.2, 462, 470, 474, 72/475
See application file for complete search history.

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(57) **ABSTRACT**

A product including a top surface part, a vertical wall part connected to an end of the top surface part and a corner part interposed between the top surface part and the vertical wall part is manufactured by flowing a material of the corner part toward the top surface part while applying a pressing force on a workpiece.

2 Claims, 12 Drawing Sheets

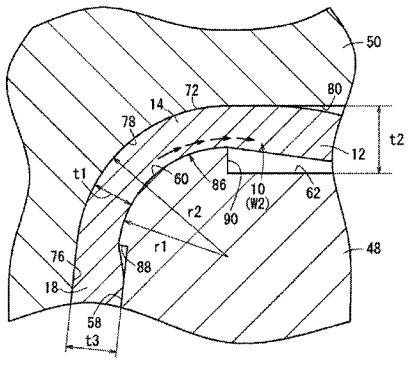


FIG. 1

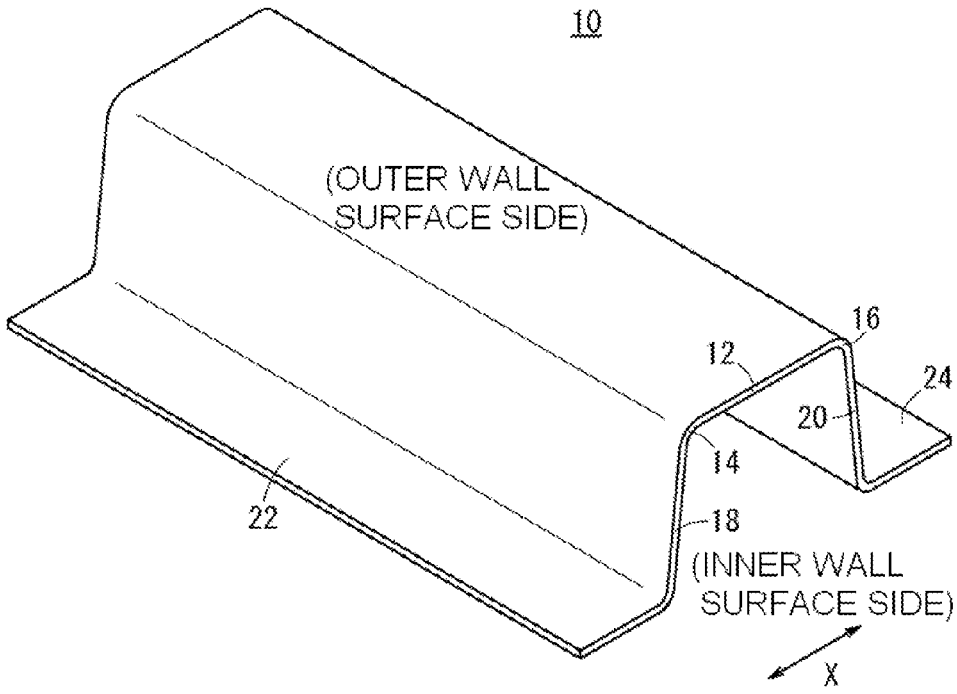

10
(OUTER WALL SURFACE SIDE)
16
12
24
20
14
22
18
(INNER WALL SURFACE SIDE)
X

FIG. 2

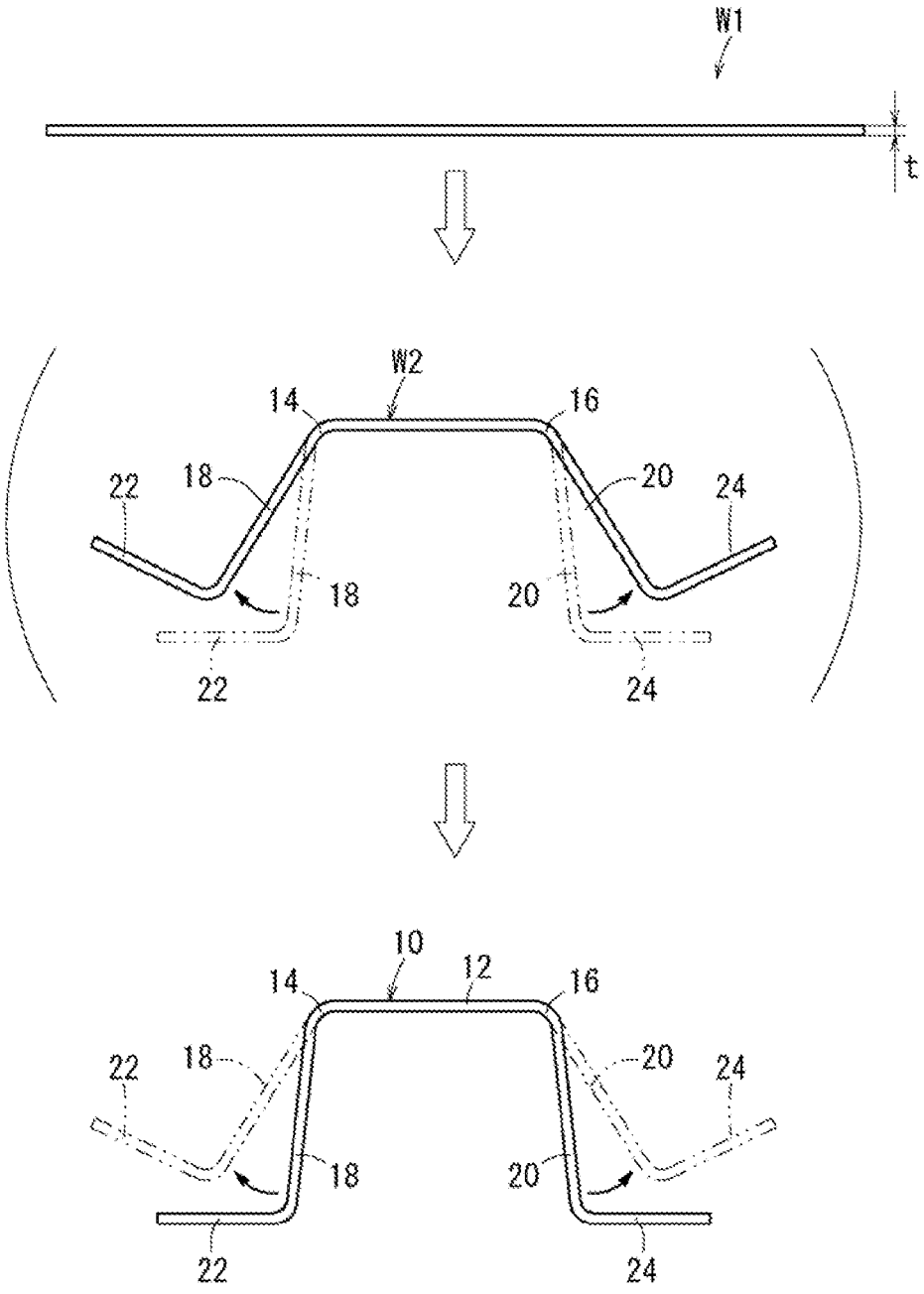


FIG. 3

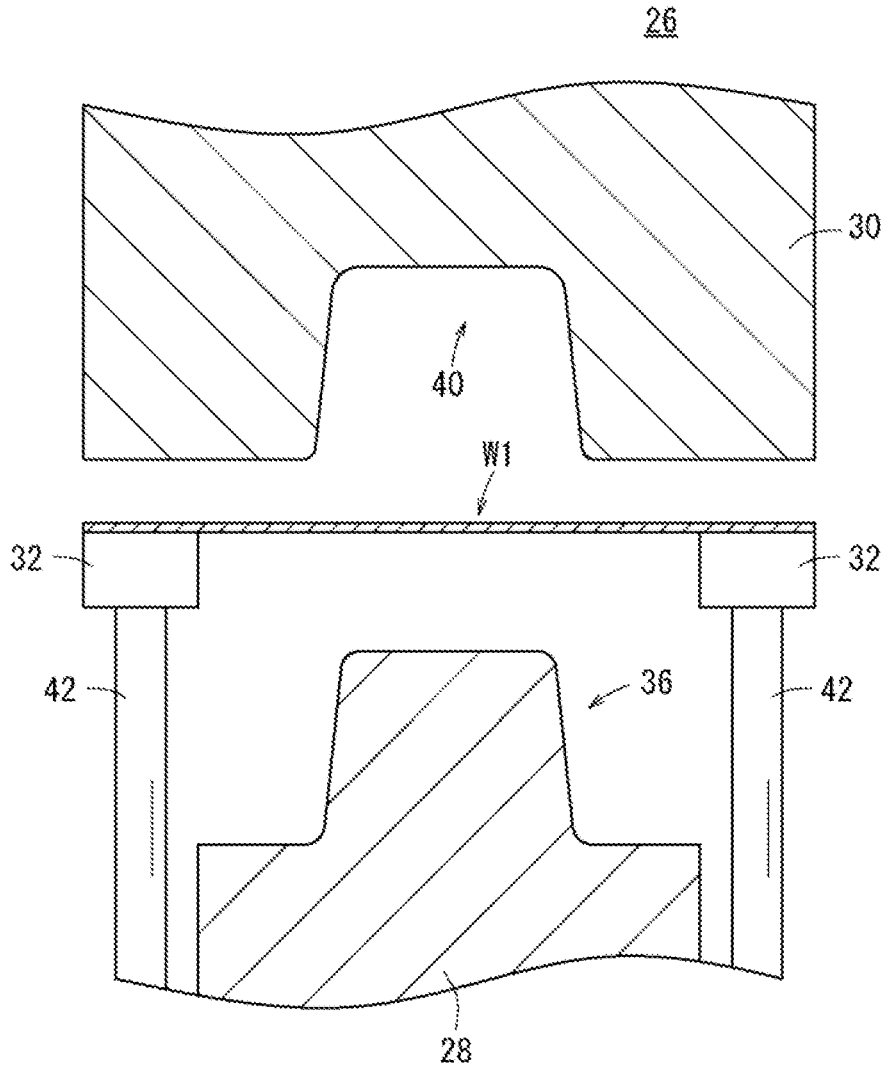


FIG. 4

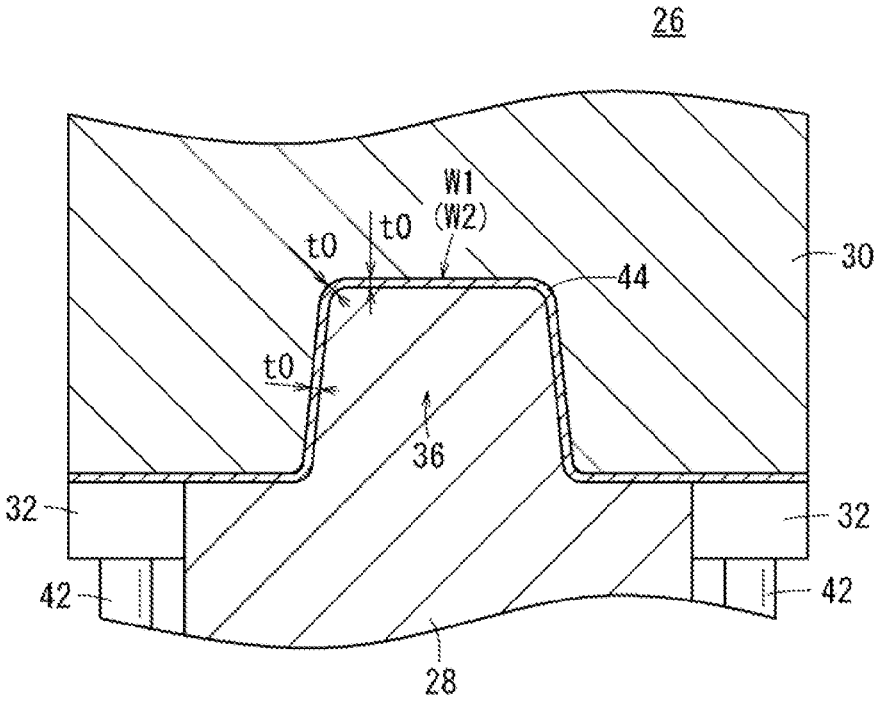


FIG. 5

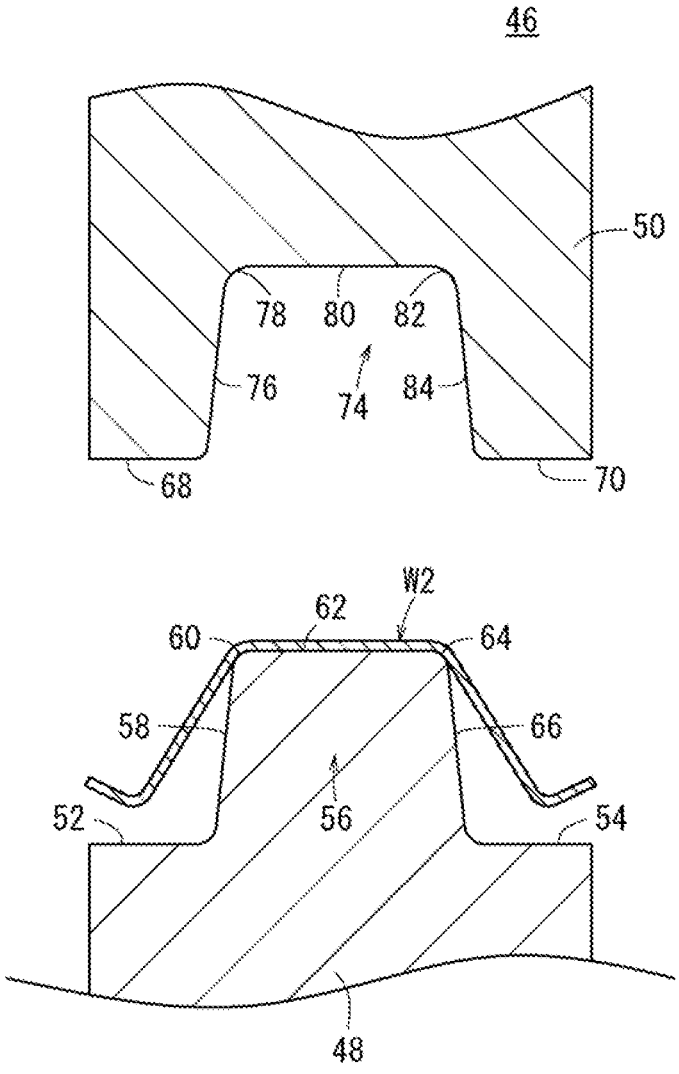


FIG. 6

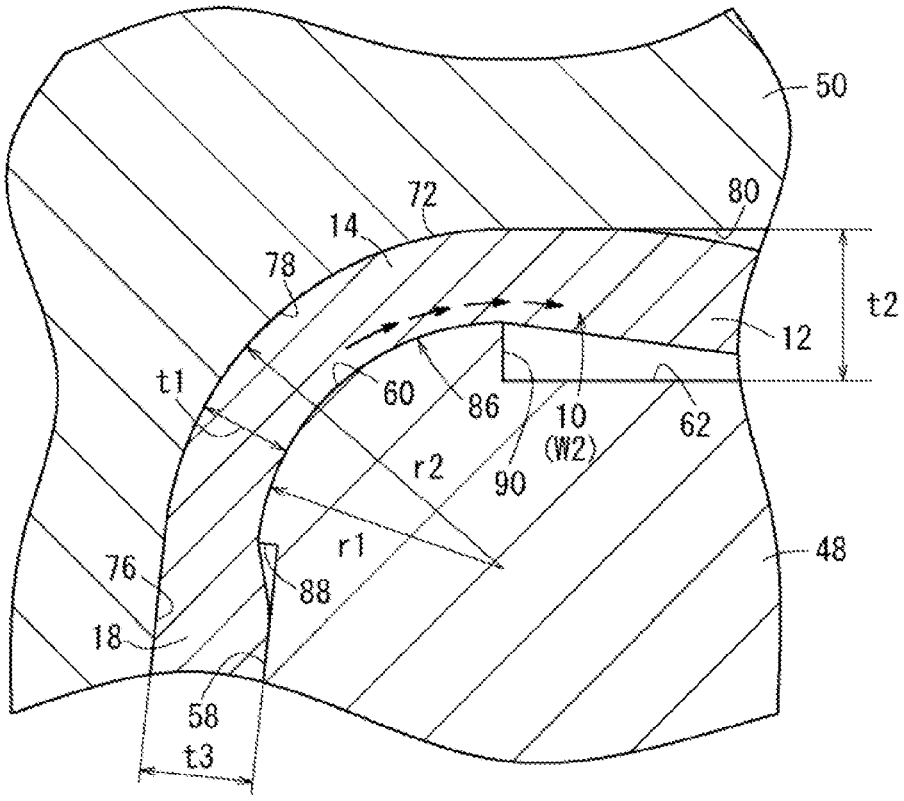


FIG. 7

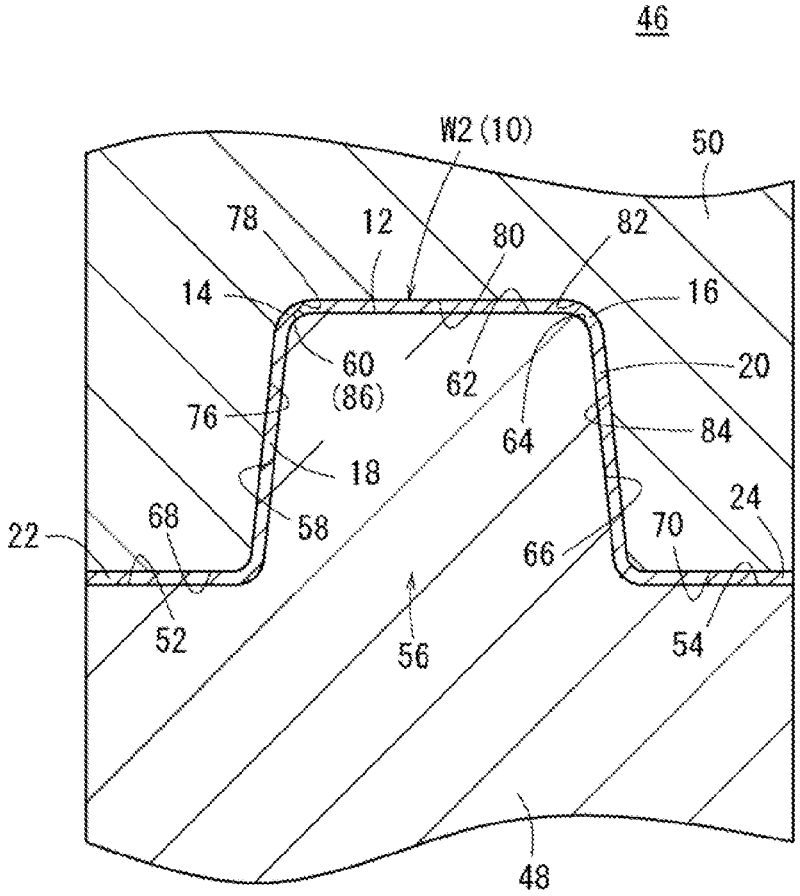

46
W2 (10)
50
78
12
80
82
14
16
60
(86)
62
20
76
64
84
18
68
58
24
22
66
70
52
56
54
48

FIG. 8

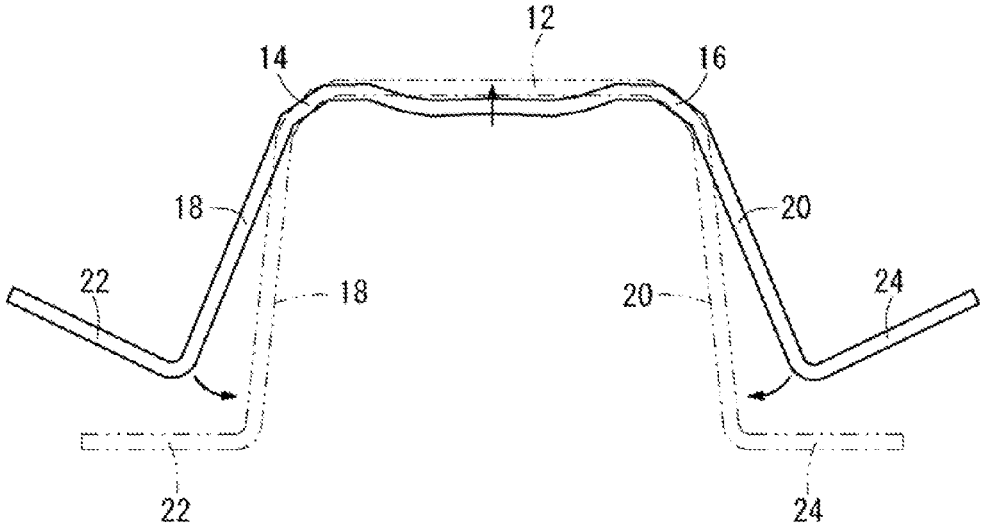


FIG. 9

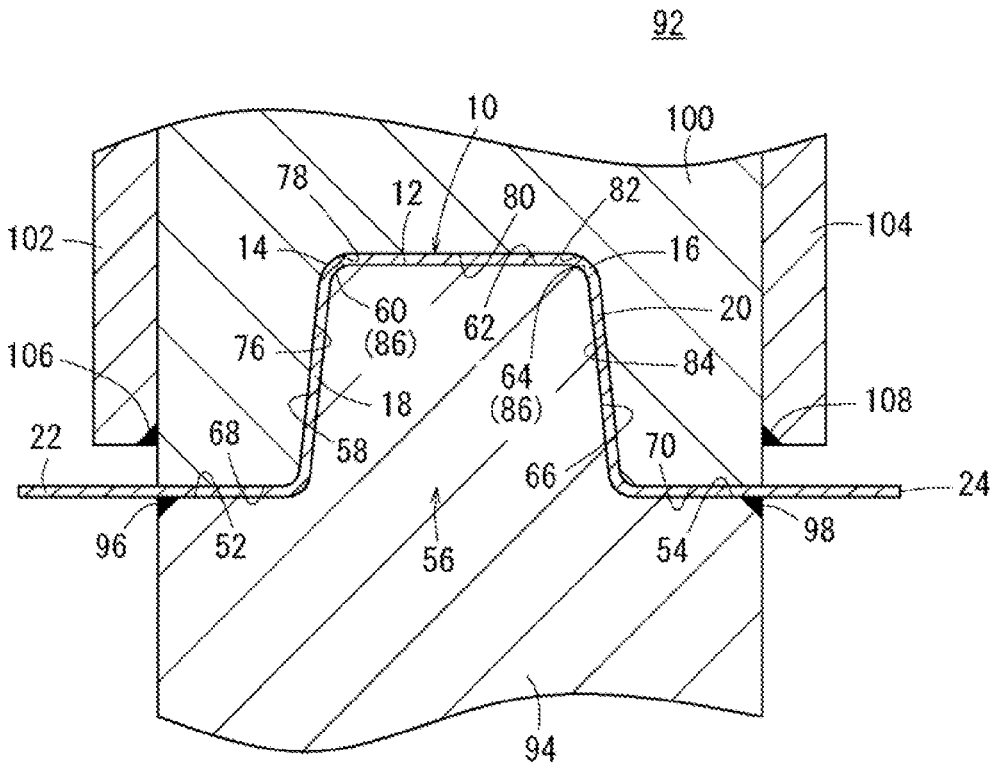
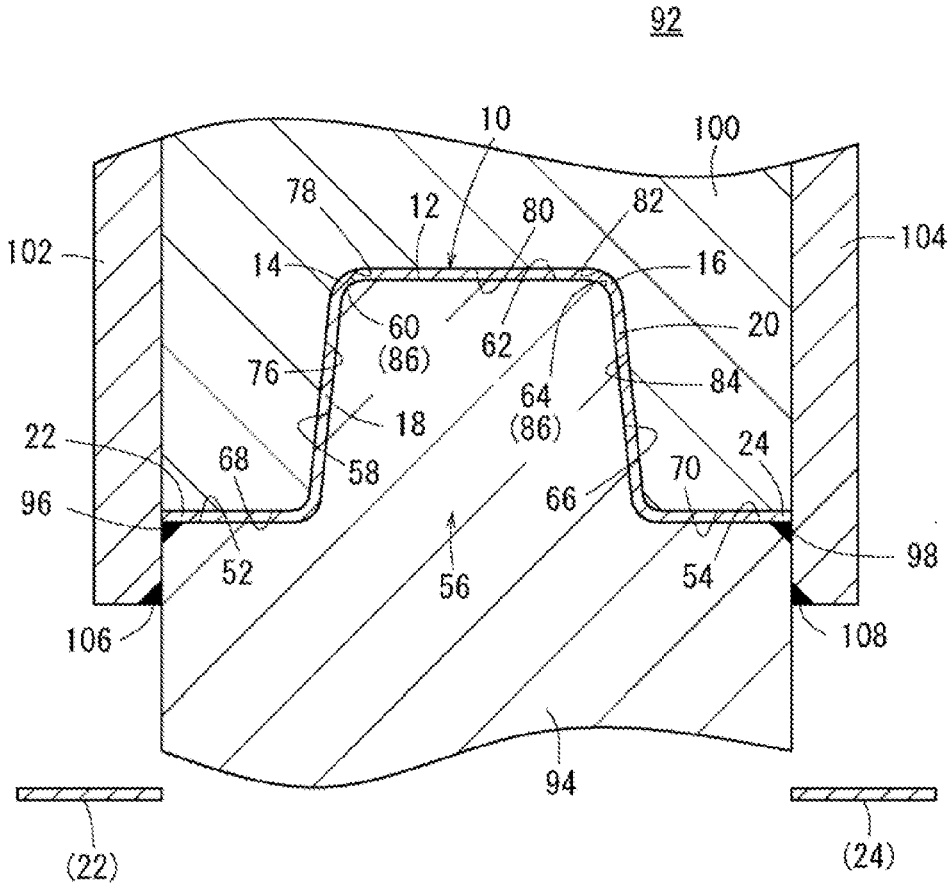

92
10
100
78
12
80
82
102
14
16
104
60
(86)
62
20
106
76
64
(86)
84
18
108
22
68
58
70
66
24
96
52
56
54
98
94

FIG. 10


92
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(86)
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(86)
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56
54
106
108
94
(22)
(24)

FIG.11

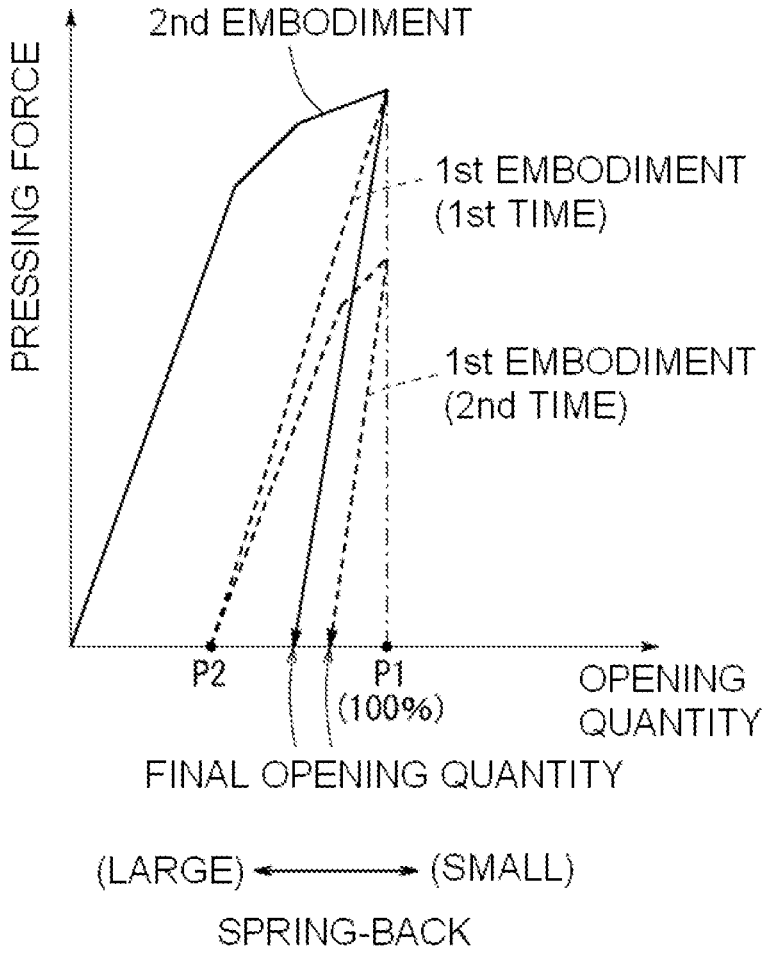
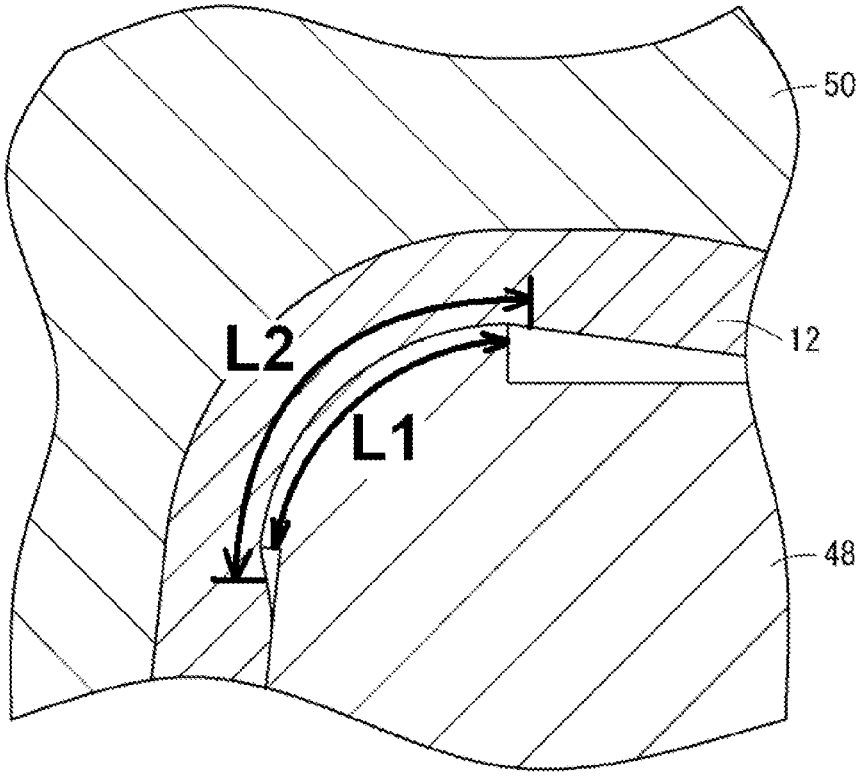

2nd EMBODIMENT
PRESSING FORCE
1st EMBODIMENT
(1st TIME)
1st EMBODIMENT
(2nd TIME)
P2
P1
(100%)
OPENING
QUANTITY
FINAL OPENING QUANTITY
(LARGE)
(SMALL)
SPRING-BACK

FIG. 12



MANUFACTURING METHOD OF PRESS PRODUCT AND PRESS FORMING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a manufacturing method of a press product and a press forming apparatus capable of obtaining a product by bending a workpiece.

2. Related Art

For example, when a corner part is formed on a metal plate by a drawing process or a bending process, a press forming of the metal plate is performed by applying a predetermined pressing force on the metal plate to bend the metal plate by a predetermined angle. As a result, a product having the corner part and its surrounding parts is obtained. However, if the product is released from the pressing force, the corner part and its surrounding parts bounce in a direction opposite to an applying direction of the pressing force. That is, so-called spring-back is occurred. Especially, the spring-back is remarkable in a high tensile strength material such as a high tensile steel plate.

Of course, the forming die for performing the press forming process is set so that an angle of the corner part of the metal plate after the spring-back occurs corresponds to a predetermined angle. That is, the forming die is designed in consideration of the spring-back so that a product having a desired shape is obtained.

However, even if the forming die thus designed is used to perform the press forming process, there is often the case that a real quantity of the spring-back is different from an estimated quantity of the spring-back. In this case, it is necessary to amend the forming die.

As such, dimensions or the pressing force of the forming die for the press forming process leads to a final setting by repeating a test of the press forming, a correction of the forming die based on the real quantity of the spring-back and retest of the press forming. On this account, the number of the process leading up to the final setting is increased and a long manufacturing time is required.

Accordingly, it is required to reduce the spring-back as far as possible. In this case, since the non-uniformity in the amount of the spring-back is also decreased, it is easy to estimate the amount of the spring-back. As a result, it is expected that the number of the process leading up to the final setting of the forming die is reduced and the manufacturing time is short.

JP-A-08-215759 discloses a technique for locally upsetting the workpiece in order to reduce the spring-back. Specifically, a forming die having a protrusion presses a corner part of the workpiece and thus the corner part is plastically deformed. As a result, a golf club head of which thickness is locally thin is obtained.

In the technique disclosed in JP-A-08-215759, the corner part of the workpiece is locally pressed by the protrusion while the workpiece is constrained in the forming die. Therefore, the workpiece is clinched by the protrusion and thus the material is difficult to flow during the press forming process. For this reason, there is a risk that the workpiece is broken. Further, since the thickness of the corner part is locally thin, the strength of the corner part is degraded. Consequently, it is difficult to adopt such a press-product as a high strength structural material such as a vehicle panel, for example.

SUMMARY OF THE INVENTION

One or more embodiments of the invention relate to a manufacturing method of a press product and a press forming apparatus capable of preventing a spring-back from occurring in the press-product which is subjected to a bending process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an overall perspective view schematically illustrating a press-product.

FIG. **2** is a schematic side view illustrating a workpiece machining process according to a first embodiment.

FIG. **3** is a longitudinal sectional view schematically illustrating a main part of a first press forming apparatus according to the first embodiment.

FIG. **4** is a longitudinal sectional view schematically illustrating a main part of the first press forming apparatus in a state where the upper die constituting the first press forming apparatus is maximally lowered.

FIG. **5** is a longitudinal sectional view schematically illustrating a main part of a second press forming apparatus according to the first embodiment.

FIG. **6** is a longitudinal sectional view schematically illustrating a main part of an area for forming a corner part in the second press forming apparatus.

FIG. **7** is a longitudinal sectional view schematically illustrating a main part of the first press forming apparatus in a state where the upper die constituting the second press forming apparatus is maximally lowered.

FIG. **8** is a side view schematically illustrating a press-product which is obtained by the press forming method according to the embodiment and is deformed after a pressing force is released.

FIG. **9** is a longitudinal sectional view schematically illustrating a main part of a press forming apparatus for a trimming process according to the first embodiment.

FIG. **10** is a longitudinal sectional view schematically illustrating a main part of the press forming apparatus in a state where the trim die constituting the second press forming apparatus of FIG. **9** is maximally lowered.

FIG. **11** is a graph illustrating a percentage of an opening quantity of the first slant wall and the second slant wall of the press-product relative to a target value respectively in the first embodiment and a second embodiment.

FIG. **12** is a view indicating a length L**1** an arc portion of an arc-shaped protruding portion and a length L**2** of an inner wall surface of a first corner part on FIG. **6**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, embodiments of a manufacturing method of a press product and a press forming apparatus will be described in detail by the referring to accompanying drawings. The embodiments and their modifications described herein are not intended to limit the invention but only to exemplify the invention, and all features or combinations of the features of the embodiments and the modifications are not always essential to the invention. In a first embodiment, a case of obtaining a press-product **10** illustrated in FIG. **1** from a plate-shaped workpiece will be described as an example.

The press-product **10** will be described. The press-product **10** is obtained from a workpiece W**1** (see, FIG. **2**) which is made of high tensile steel and has an initial thickness t, for example. The press-product **10** includes a ceiling wall **12** as a top surface part, a first corner part **14** and a second corner part **16** as corner parts, a first slant wall **18** and a second slant wall **20** as vertical wall parts. The ceiling wall **12** extends in

a horizontal direction (arrow X direction in FIG. **1**). The first slant wall **18** is continued to the ceiling wall **12** via the first corner part **14** and the second slant wall **20** is continued to the ceiling wall **12** via the second corner part **16**. Further, a first flange **22** and a second flange **24** are respectively continued to the first slant wall **18** and the second slant wall **20**. The first flange **22** and the second flange **24** extend parallel to the extending direction of the ceiling wall **12**.

The first slant wall **18** and the second slant wall **20** are joined to the ceiling wall **12** in an approximately 90 degree. The first slant wall **18** and the second slant wall **20** may be slightly inclined to the vertical direction. In this case, the ceiling wall **12** forms a slightly open U shape together with the first slant wall **18** and the second slant wall **20**. Further, each of an angle between the first slant wall **18** and the ceiling wall **12** and an angle between the ceiling wall **12** and the second slant wall **20** is approximately 90 degree in the inner wall side of the first corner part **14** and the second corner part **16** and is approximately 270 degree in the outer wall side thereof.

As discussed below, the first corner part **14**, the second corner part **16**, the first slant wall **18**, the second slant wall **20**, the first flange **22** and the second flange **24** are formed by performing a bending process (press forming process) for the workpiece W**1** having the initial thickness t.

As illustrated in FIG. **2**, the press-product **10** thus shaped can be manufactured through a first press forming process in which a preform W**2** is obtained from the workpiece W**1** and a second press forming process in which the press-product **10** is obtained from the preform W**2**. Hereinafter, this case will be described as a first embodiment.

Herein, a first press forming apparatus **26** for performing the first press forming process will be described by referring to FIGS. **3** and **4**. The first press forming apparatus **26** performs so-called drawing process. The first press forming apparatus **26** includes a first lower die **28**, a first upper die **30** and a plurality of blank holders **32**. The first lower die **28** is a forming die for bending the workpiece W**1**. The first upper die **30** is approaching or retreating from the first lower die **28** under the action of a lifting mechanism (not illustrated). The blank holders is configured to retain the workpiece W**1**. Herein, two of the pluralities of blank holder **32** are illustrated in FIG. **2**.

That is, in this case, the first lower die **28** is a fixed die which is fixedly positioned and the first upper die **30** is a movable die which can be displaced. The first lower die **28** includes a first convex portion **36** and therefore has a convex shape toward the first upper die **30**. Meanwhile, the first upper die **30** is provided with a first concave portion **40** into which the first convex portion **36** of the first lower die **28** moves and therefore has a concave shape due to the first concave portion **40**.

The pluralities of blank holder **32** are provided to surround the first lower die **28** and respectively supported on cushion pins **42** which extend from a biasing means (not illustrated). The blank holders **32** can be displaced in accordance with an advancing (lifting) or retreating (lowering) action of the cushion pin **42** in a vertical direction in FIG. **3**.

As illustrated in FIG. **4**, when the first lower die and the first upper die are closed, the first convex portion **36** moves into the first concave portion **40** and thus a first cavity **44** is formed.

A clearance between the first lower die **28** and the first upper die **30** corresponds to the initial thickness t of the workpiece W**1**.

Next, a second press forming apparatus **46** as a press forming apparatus according to the first embodiment will be described by referring to FIGS. **5** and **6**. Naturally, the second press forming apparatus **46** is configured to perform the second press forming process.

The second press forming apparatus **46** includes a second lower die **48** on which the preform W**2** is placed and a second upper die **50** which is approaching or retreating from the second lower die **48** under the action of a lifting mechanism (not illustrated). Also, in this case, the second lower die **48** is a fixed die which is fixedly positioned and the second upper die **50** is a movable die which can be displaced.

The second lower die **48** includes a first flange forming surface **52** for forming the first flange **22**, a second flange forming surface **54** for forming the second flange **24** and a second convex portion **56** interposed between the first flange forming surface **52** and the second flange forming surface **54**. The second lower die **48** has a convex shape toward the second upper die **50** due to the second convex portion **56**.

The second convex portion **56** includes a first slant forming surface **58**, a first corner forming surface **60**, a first top forming surface **62**, a second corner forming surface **64** and a second slant forming surface **66** which are provided in this order from the first flange forming surface **52** toward the second flange forming surface **54**. Naturally, the first slant forming surface **58** and the second slant forming surface **66** are configured to form the first slant wall **18** and the second slant wall **20**. The first corner forming surface **60** and the second corner forming surface **64** are configured to form the first corner part **14** and the second corner part **16**. Further, the first top forming surface **62** retains the portion of the preform W**2** corresponding to the ceiling wall **12** of the press-product **10** in collaboration with the second upper die **50**.

The second upper die **50** includes a third flange forming surface **68**, a fourth flange forming surface **70** and a second concave portion **74** interposed between the third flange forming surface **68** and the fourth flange forming surface **70**. As the second convex portion **56** moves into the second concave portion **74**, a second cavity **72** (see, FIG. **6**) is formed between the second convex portion **56** and the second concave portion **74**. The second upper die **50** has a concave shape due to the second concave portion **74**.

The second concave portion **74** includes a third slant forming surface **76**, a third corner forming surface **78**, a second top forming surface **80**, a fourth corner forming surface **82** and a fourth slant forming surface **84** which are provided in this order from the third flange forming surface **68** toward the fourth flange forming surface **70**. Herein, the third slant forming surface **76** and the fourth slant forming surface **84** are respectively opposed to the first slant forming surface **58** and the second slant forming surface **66**. The third corner forming surface **78** and the fourth corner forming surface **82** are respectively opposed to the first corner forming surface **60** and the second corner forming surface **64**. Further, the second top forming surface **80** retains the portion of the preform W**2** corresponding to the ceiling wall **12** of the press-product **10** in collaboration with the first top forming surface **62** of the second lower die **48**.

Herein, FIG. **6** is an enlarged view illustrating the vicinity of the first corner forming surface **60** in a state where the second lower die and the second upper die are closed. As is apparent from FIG. **6**, the first corner forming surface **60** is provided with an arc-shaped protruding portion **86** protruding therefrom. That is, a step **88** is formed between the arc-shaped protruding portion **86** and the first slant forming surface **58** and a step **90** is formed between the arc-shaped protruding portion **86** and the first top forming surface **62**.

In the first embodiment, in the second cavity **72**, the following equation (1) is established.

$$t1<t<t2 \quad (1)$$

where t**1** is a clearance between the arc-shaped protruding portion **86** and the third corner forming surface **78**, t**2** is a clearance between the first top forming surface **62** and the second top forming surface **80** and t is the initial thickness of the workpiece W**1**.

That is, the clearance t**1** between the arc-shaped protruding portion **86** and the third corner forming surface **78** is set smaller than the initial thickness t of the workpiece W**1** prior to performing the press forming process. Further, the clearance t**2** between the first top forming surface **62** and the second top forming surface **80** is set larger than the initial thickness t of the workpiece W**1** prior to performing the press forming process.

Further, in this embodiment, the step **90** is set larger than the step **88**.

It is preferred that the protruding amount of the arc-shaped protruding portion **86**, that is, the height of the steps **88** and **90** falls within the range of 1% to 12% of the initial thickness t of the workpiece W**1**.

Further, it is more preferred that the length L**1** of an arc portion in the arc-shaped protruding portion **86**, the length L**2** of an inner wall surface in the first corner part **14** and the initial thickness t of the workpiece W**1** satisfy the following equation (2).

$$L1=L2\pm t \quad (2)$$

The "L**1**" and "L**2**" are indicated in FIG. **12**.

When equation L**1**>L**2**+t is established, a bending effect due to a moment tends to be decreased. On the contrary, when equation L**1**<L**2**−t is established, a compression action tends to be decreased.

The third corner forming surface **78** is formed as a simple arc-shaped corner surface having a radius r**2** of curvature. The radius r**2** of curvature is set to allow an outer wall surface of the first corner part **14** to be curved in a predetermined radius curvature.

Further, in the first embodiment, a clearance t**3** between the first slant forming surface **58** of the second lower die **48** and the third slant forming surface **76** of the second upper die **50** is set equal to or slightly smaller than the initial thickness t of the workpiece W**1**.

The above configurations can be similarly applied to the second corner forming surface **64** and the fourth corner forming surface **82**. Accordingly, a detailed description thereof will be omitted.

The first press forming apparatus **26** and the second press forming apparatus **46** according to the first embodiment are basically configured as mentioned above. Next, effects theses forming apparatus will be described with reference to the relationship with the press forming method.

In the first embodiment, the workpiece W**1** is subjected to the first press forming process to obtain a preform W**2**. And then, the preform W**2** is subjected to the second press forming process to alleviate a spring-back occurred in the preform W**2** (see, FIG. **2**).

First, the first press forming apparatus illustrated in FIG. **3** is used to perform a first press forming process for a plate-shaped workpiece W**1**.

When the workpiece is subjected to the first press forming process, the workpiece W**1** is first placed between the first lower die **28** and the first upper die **30** in a state where these dies are open. At this time, the workpiece W**1** is placed on the blank holder **32**. In this state, all cushion pins **42** are maximally elevated.

Subsequently, in order to perform the press forming process, the lifting mechanism is biased to lower the first upper die **30** and thereby the first lower die approaches to the first lower die **28**. The surface of the first upper die **30** opposite to the blank holder **32** is first contact with a portion of the workpiece W**1** placed on the blank holder **32**.

As the first lower die **30** is further lowered, all cushion pins **42** are simultaneously lowered by an urging force of the first upper die **30**. That is, the pluralities of blank holders **32** are simultaneously lowered.

The first upper die **30** is continuously lowered. By doing so, the cushion pins **42** are further operated and the first convex portion **36** of the first lower die **28** and a part of the workpiece W**1** moves into the first concave portion **40** of the first upper die **30**.

As illustrated in FIG. **4**, as the first upper die **30** is maximally lowered, the cushion pin **42** is also maximally lowered. At this time, the workpiece W**1** is held by the first lower die **28** and the blank holder **32** and the first upper die **30**. Further, the workpiece W**1** is formed into a shape corresponding to the shape of the first cavity **44** which is formed by the first concave portion **40** and the first convex portion **36** entering the first concave portion **40**. Thereby, the first press forming process is finished to obtain the preform W**2** illustrated in FIG. **2**.

Thereafter, the first upper die **30** is spaced apart from the first lower die **28** under the action of the lifting mechanism to open the dies. Thereby, the preform W**2** can be separated from the first press forming apparatus **26**. In the prior art, the preform W**2** thus obtained is utilized as a product as it is. However, in this preform W**2**, the amount of the spring-back is relatively large, as illustrated in FIG. **2**.

For this reason, the second press forming process is subsequently performed. Specifically, the preform W**2** is set into the second lower die **48** of the second press forming apparatus **46** illustrated in FIG. **5**. In order to perform the press forming process, the lifting mechanism is biased to lower the second upper die **50**, so that the second upper die approaches the second lower die **48**. As the second upper die **50** is further lowered, the second convex portion **56** of the second lower die **48** and a part of the preform W**2** enter the second concave portion **74** of the second upper die **50**.

At this time, one end of the preform W**2** is held between the first flange forming surface **52** and the third flange forming surface **68** and the other end thereof is held between the second flange forming surface **54** and the fourth flange forming surface **70**. Thereby, the first flange **22** and the second flange **24** are formed. Further, a part of the preform W**2** interposed between the first top forming surface **62** and the second top forming surface **80** is formed as the ceiling wall **12**.

Simultaneously, as most of the preform W**2** and the second convex portion **56** enter the second concave portion **74**, a bending process for the preform W**2** is performed. As a result, the first slant wall **18** and the first corner part **14** are formed between the first flange **22** and the ceiling wall **12**. And, the second corner part **16** and the second slant wall **20** are formed between the ceiling wall **12** and the second flange **24**.

FIG. **6** illustrates a part which is formed into the first corner forming surface **60** (arc-shaped protruding portion **86**) and the third corner forming surface **78**. As mentioned above, the clearance t**1** between the arc-shaped protruding portion **86** and the third corner forming surface **78** is set

smaller than the initial thickness t of the workpiece W1 and the clearance t2 between the first top forming surface **62** and the second top forming surface **80** is set larger than the initial thickness t of the workpiece W1. Accordingly, the preform W2 is pressed between the arc-shaped protruding portion **86** and the third corner forming surface **78**, but is not pressed between the first top forming surface **62** and the second top forming surface **80**. Furthermore, in this embodiment, the clearance t3 between the first slant forming surface **58** and the third slant forming surface **76** is set equal to or slightly smaller than the initial thickness t of the workpiece W1. Accordingly, the first slant wall **18** is held between the first slant forming surface **58** and the third slant forming surface **76** and thus constrained.

Therefore, a part of material which is formed into the first corner part **14** is flowing toward the ceiling wall **12**, as illustrated by an arrow in FIG. **6**. This is because the preform W2 is not constrained between the first top forming surface **62** and the second top forming surface **80** as stated above and thus the material is liable to flow into the clearance therebetween. Especially, such a phenomenon is prominent on the inner wall surface of arc-shaped protruding portion **86**.

Owing to the flowing of the material as mentioned above, the inner wall surface (lower end surface) of the ceiling wall **12** is slightly bent toward the first top forming surface **62**. In other words, the inner wall surface is warped. In this way, it is possible to avoid the material on a side of the inner wall surface of the first corner part **14** to be excessive and to avoid the material on a side of the outer wall surface thereof to be short. Further, the first corner part **14** is pressed in a plate thickness direction thereof so that the difference between the compressive residual stress on the inner wall surface and the tensile residual stress on the outer wall surface can be reduced.

Although illustration and detailed description will be omitted, the same phenomenon can be occurred in the second corner part **16**.

When the second upper die **50** is maximally lowered, as illustrated in FIG. **7**, the second press forming process is finished to obtain the press-product **10** illustrated in FIG. **1**.

And then, the second upper die **50** is spaced apart from the second lower die **48** under the action of the lifting mechanism to open the dies. Thereby, the press-product **10** can be separated from the second press forming apparatus **46**.

As mentioned above, in the preform W2 obtained by performing the first press forming process, a relatively large amount of spring-back is occurred in the first corner part **14** and the second corner part **16**, as illustrated in FIG. **2**. As a result, the first slant wall **18** and the second slant wall **20** bounce in a direction opposite to the pressing direction during the press forming, that is, toward the ceiling wall **12**. The reason is as follows. That is, since compressive residual stress occurs on the inner wall surface of the first corner part **14** and the second corner part **16** and a large tensile residual stress occurs on the outer wall surface thereof, the first slant wall **18** and the second slant wall **20** try to return back to their original position by the action of the large tensile residual stress on the outer wall surface if the first slant wall **18** and the second slant wall **20** is released from a pressing force.

On the contrary, in the press-product **10** obtained by the press forming method according to the first embodiment, the amount of the spring-back is relatively small, as compared to the prior art. This is considered due to the fact that since a material for the preform W2 is caused to flow toward the ceiling wall **12** in the process of forming the first corner part **14** and the second corner part **16**, the following phenomenon occurs.

That is, since the first corner part **14** and the second corner part **16** are pressed in the thickness direction thereof, it is possible to reduce the difference between the tensile residual stress on the outer wall surface of the first corner part **14** and the second corner part **16** and the compressive residual stress on the inner wall surface thereof. Furthermore, as the material flows toward the ceiling wall **12**, the ceiling wall **12** is slightly bent toward the first top forming surface **62**, as mentioned above. At this time, when the dies are opened, the bent state is returned to its original position. By such a return operation, the first slant wall **18** and the second slant wall **20** are displaced in a direction of the inner wall surface, thereby approaching to each other. That is, a force is applied in a direction to cancel the spring-back of the first corner part **14** and the second corner part **16**. Thereby, the bounce of the first slant wall **18** and the second slant wall **20** is suppressed.

Further, since the material of the preform W2 flows easily, the local stretch of the first corner part **14** and the second corner part **16** can be suppressed and thus breakage concerns can be dispelled. Especially, in a case where the protruding amount of the arc-shaped protruding portion **86** (see, FIG. **6**) is set within a range of 1 to 12% of the initial thickness t of the workpiece W1, the material of the preform W2 flows further easily.

Further, by setting the length L1 of an arc portion in the arc-shaped protruding portion **86**, the length L2 of an inner wall surface in the first corner part **14** and the initial thickness t of the workpiece W1 to satisfy the above equation (2), it is possible to secure a sufficient bending effect and to avoid an insufficient compression.

In the second press forming process, a trimming process may be performed.

In this case, the preform W2 obtained by the first press forming process is set on the third lower die **94** of a press forming apparatus **92** (hereinafter, simply referred to as press forming apparatus) for performing the trimming process, as illustrated in FIG. **9**. Herein, the third lower die **94** of the press forming apparatus **92** has same configuration as the second lower die **48** of the press forming apparatus **46**, except for including lower blades **96**, **98**. Accordingly, the same or similar element will be denoted by the same reference numeral as that of the second lower die **48** and detailed description thereof will be omitted.

The press forming apparatus **92** further includes trim dies **102**, **104**. The trim dies **102**, **104** are provided with upper blades **106**, **108** and can be displaced in a vertical direction under the action of a lifting mechanism (not illustrated) which is different from a lifting mechanism for lifting a third upper die **100**.

After the preform W2 is set on the third lower die **94** of the press forming apparatus **92**, the dies are closed in a state illustrated in FIG. **9**. Since the arc-shaped protruding portion **86** is protruding from the first corner forming surface **60** and the second corner forming surface **64** of the third lower die **94**, similar to the configuration illustrated in FIG. **6**, the material for the first corner part **14** and the second corner part **16** of the preform W2 flows toward the ceiling wall **12**. Accordingly, the material of the ceiling wall **12** is bent toward the first top forming surface **62**.

Thereafter, as illustrated in FIG. **10**, the trim dies **102**, **104** are lowered under the action of the lifting mechanism. At this time, a part of the first flange **22** and the second flange **24** of the press-product **10** is cut away by the lower blades

96, 98 and the upper blades 106, 108. Accordingly, a press-product 10 with a predetermined length can be obtained.

Subsequently, the dies are opened to take out the press-product 10. For the same reason as mentioned above, the amount of the spring-back is also reduced in this press product 10.

Although the press-product 10 is formed by performing the first press forming process and the second press forming process in the foregoing first embodiment, the press-product 10 may be formed by performing single press forming process for the plate-shaped workpiece W1. Hereinafter, this case will be described as a second embodiment.

In the second embodiment, the press-product 10 is obtained directly from the plate-shaped workpiece W1. That is, first, the workpiece W1 is placed on the second lower die 48 of the second press forming apparatus 46.

Thereafter, a forming process is performed as in the second press forming process in the first embodiment. That is, as illustrated in FIG. 4, the second upper die 50 of the second press forming apparatus 46 is lowered. At this time, as the second convex portion 56 of the second lower die 48 and a part of the workpiece W1 enter the second concave portion 74 of the second upper die 50, a bending process for the workpiece W1 is performed to form a corner part, that is, the first corner part 14 and the second corner part 16. Further, a part corresponding to the ceiling wall 12 is retained on the first top forming surface 62.

Since the first corner part 14 is pressed between the first corner forming surface 60 (arc-shaped protruding portion 86) and the third corner forming surface 78 and the second corner part 16 is pressed between the second corner forming surface 64 (arc-shaped protruding portion 86) and the fourth corner forming surface 82, the material for the corner part flows toward the ceiling wall 12. As a result, a force is applied in a direction to reduce the spring-back of the first corner part 14 and the second corner part 16 and therefore the amount of the spring-back can be suppressed, as in the first embodiment. Herein, in the second embodiment, the relationship between the initial thickness t of the workpiece W1 and the clearances t1 to t3 in the second press forming apparatus 46 is same as the first embodiment.

FIG. 11 illustrates a percentage of an opening quantity of the first slant wall 18 and the second slant wall 20 relative to a target value respectively in the first embodiment and the second embodiment. The point 1 in FIG. 11 represents a state where an actual opening quantity coincides with the target value and this state is referred to as 100%. As the spring-back is larger, the percentage is smaller. Further, the point P2 in FIG. 11 represents an amount of the spring-back occurred in the preform W2 due to the first press forming process of the first embodiment, that is, an amount of the spring-back occurred in a conventional press forming process.

As is apparent from FIG. 11, the percentage of the opening quantity in the first embodiment is larger than that of the opening quantity in the second embodiment. That is, an amount of the spring-back in the first embodiment is smaller than that of the spring-back in the second embodiment. This means that an amount of the spring-back can be further reduced by twice press forming process.

The present invention is not limited to the first embodiment and the second embodiment mentioned above and can be variously modified without departing from the gist of the invention.

For example, although the step 88 is formed between the arc-shaped protruding portion 86 and the first slant forming surface 58 and the step 90 is formed between the arc-shaped protruding portion 86 and the first top forming surface 62 in FIG. 6, a slant part or a corner part may be provided, instead of the steps 88, 90. Specifically, the arc-shaped protruding portion 86 and the first slant forming surface 58 (second slant forming surface 66) and also the arc-shaped protruding portion 86 and the first top forming surface 62 are respectively connected to each other via the slant part or the corner part.

Further, the second lower die 48 and the third lower die 94 may have a concave shape and the second upper die 50 and the third upper die 100 may have a convex shape. In this case, the inner wall surface of the press-product 10 is opposed to the second upper die 50 and the third upper die 100 and the outer wall surface thereof is opposed to the second lower die 48 and the third lower die 94. Accordingly, the arc-shaped protruding portion 86 can be formed on the second upper die 50 and the third upper die 100.

According to the above embodiments, a method of manufacturing a product 10 including a top surface part 12, a vertical wall part 18, 20 connected to an end of the top surface part 12 and a corner part 14, 16 interposed between the top surface part 12 and the vertical wall part 18, 20 by applying a pressing force on a workpiece W1, W2, may include a step of flowing a material of the corner part 14, 16 toward the top surface part 12.

The above method may further include a step of applying a pressing force on the corner part 14, 16 while constraining the vertical wall part 18, 20.

The above method may further include a step of forming pre-bent part on a part of the workpiece to be formed as the corner part 14, 16, prior to forming the corner part 14, 16, and a step of bending the pre-bent part in which a spring-back occurs in a direction opposite to the direction of the spring-back to form the corner part 14, 16.

Moreover, according to the above embodiments, a press forming apparatus configured to form a product 10 including a top surface part 12, a vertical wall part 18, 20 connected to an end of the top surface part 12 and a corner part 14, 16 interposed between the top surface part 12 and the vertical wall part 18, 20, may include a first forming die 48, 94 and a second forming die 50, 100 adapted to apply a pressing force on a workpiece W1, W2. In a condition that a cavity 72 is formed between the first forming die 48, 94 and the second forming die 50, 100, a clearance t1 between the first forming die and the second forming die at an area for forming the corner part 14, 16 may be smaller than a thickness t of the workpiece, and a clearance t2 between the first forming die and the second forming die at an area for forming the top surface part 12 may be larger than the thickness t of the workpiece.

In the above apparatus, the first forming die 48, 94 may include a convex portion 56 having a top forming surface 62 corresponding to the top surface part 12, a vertical wall forming surface 58, 66 corresponding to the vertical wall part 18, 20, and a corner forming surface 60, 64 positioned between the top forming surface 62 and the vertical wall forming surface 58, 66 and corresponding to the corner part 14, 16. The second forming die 50, 100 may include a concave portion 74 into which the convex portion 56 enters to form the cavity 72 between the convex portion 56 and the concave portion 74. A protruding portion 86 may be formed on the corner forming surface 60, 64 of the convex portion 56, wherein each of the protruding portion 86 is adapted to

apply a pressing force on the corner part **14**, **16** in a direction from an inner wall surface toward an outer wall surface of the corner part **14**, **16**.

In the above apparatus, a protruding amount of the protruding portion **86** may be within a range of 1% to 12% of the thickness t of the workpiece.

According to the method and the apparatus of the embodiments, since the corner parts are pressed in a plate thickness direction thereof, the difference between the compressive residual stress on the inner wall surface of the corner part and the tensile residual stress on the outer wall surface thereof can be reduced. Accordingly, a force tensioning the inner wall surface toward the outer wall surface is small. Further, since the material of the corner part is caused to flow toward the top surface part, the top surface part is slightly bent toward the inner wall surface by such a flowing of the material. Accordingly, when the dies are opened and the pressing force is released, the bent state tries to return toward the outer wall surface. By these configurations, it is possible to reduce the spring-back.

Further, since the material of the workpiece flows easily, breakage concerns of the workpiece can be dispelled.

Further, since the workpiece is pressed by the forming surface for forming the corner part, it is possible to solve the problem that the thickness of the corner part is locally thin and the strength of the corner part is degraded.

What is claimed is:

1. A method of manufacturing a press product from a workpiece, the press product including a top surface part, a vertical wall part connected to an end of the top surface part, and a corner part interposed between the top surface part and the vertical wall part, the press product being formed by applying a pressing force on the workpiece by a forming die, the method comprising:

flowing a material of the corner part toward the top surface part; and

applying a pressing force on the corner part with the forming die in a direction from an inner wall surface toward an outer wall surface of the corner part while constraining the vertical wall part and both surfaces of the corner part, with a portion of the top surface part unconstrained, such that material flows from the corner part toward the unconstrained portion of the top surface part during application of the pressing force.

2. The method according to claim **1**, further comprising:

forming a pre-bent part on a part of the workpiece to be formed as the corner part, prior to forming the corner part; and

bending the pre-bent part in which a spring-back occurs, in a direction opposite to a direction of the spring-back to form the corner part.

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